Carbon Dioxide Removal: Science, Implementation, Ethics

EAS 8803/4803 | Fall 2026

Professor: Dr. Chris Reinhard

Email: chris.reinhard@eas.gatech.edu

Class: Tu/Th | 12:30pm-1:45pm | MoSE, 1224

Office: Ford ES&T, 3104

Human fossil fuel use, agriculture, and land use change are significantly increasing the abundances of greenhouse gases in Earth's atmosphere. There is robust consensus that rapid and steep cuts to anthropogenic greenhouse gas emissions must represent the core of climate mitigation. However, there is increasing consensus that in order to limit warming since the pre-industrial period to well below 2°C we will also need to remove massive amounts of carbon dioxide from the atmosphere or decouple Earth's radiation budget from atmospheric CO_2 abundance through solar geoengineering. As a result, significant interest and debate now surround possible approaches toward *carbon dioxide removal (CDR)* – directed intervention by the human species in Earth's carbon cycle in order to transiently or permanently remove carbon dioxide from the atmosphere. A steadily increasing number of CDR pathways are currently in operation across a range of deployment scales, including afforestation/reforestation, engineered approaches such as direct air capture (DAC) or bioenergy with carbon capture and storage (BECCS), and hybrid approaches such as enhanced weathering and ocean alkalinity enhancement. In addition to the technical challenges – estimating overall radiative impact, barriers to deployment at scale, life cycle emissions – human intervention into the Earth's carbon cycle presents a range of challenges for regional and global governance, environmental ethics, and social justice. The goal of this course is to equip students with a basic working knowledge of Earth's carbon cycle and prominent carbon removal strategies, and to give them the opportunity to examine the costs, benefits, and social ramifications of carbon removal within an Earth system science framework.

Text Resources:

There is no required textbook for the course. All readings for the course will be supplied electronically. These recommended resources range from non-specialist through technical summaries.

Global Warming of 1.5°C: An IPCC Special Report | Chapter 2 | [2018]

Carbon Dioxide Removal Primer | Wilcox, J., Kolosz, B., Freeman, J. (*eds.*) | cdrprimer.org | [2021]

National Academies of Sciences Report on Negative Emissions Technologies | read online | [2019]

The State of Carbon Dioxide Removal 2024 | read online | [2024]

After Geoengineering: Climate Tragedy, Repair, and Restoration | Buck, H.J. | Verso Books | [2021]

Grading Rubric:

Attendance/participation:	30%
Group Project:	
Presentation Slides	30%
Reading Assignment	15%
Discussion Questions	15%
Contribution Statement:	10%

Project Presentation:

Goals – You will produce an original presentation summarizing the basic underlying science and challenges associated with a particular carbon removal pathway. These should clearly and efficiently communicate the basic concept of each pathway, minimizing extraneous detail without sacrificing scientific rigor. They should also clearly summarize the major issues with implementation and any associated ethical or social issues raised by your chosen pathway.

Skills – The purpose of this exercise is to create a concise but rigorous summary of the technical, practical, and ethical dimensions associated with deployment of a given carbon removal strategy. Doing this effectively will require us to:

- Explore and assimilate the scientific concepts underlying a particular carbon removal technique via interrogation of technical literature
- Metabolize and distill these concepts into a digestible form
- Create a product that clearly and rigorously communicates your understanding of the underlying technical, practical, and ethical issues.

The core skills involved in this process are important across a range of pursuits in professional science and policy work, including the design of impactful figures for peer-reviewed publications and technical reports, construction and delivery of resonant presentations at scientific conferences, and effective communication with funding agencies or other potential stakeholders across backgrounds.

Contribution Statements:

Goals – This deliverable summarizes the contributions of each group member to the overall project effort. These need not be lengthy and can follow the form now common for many scientific publications [see, for example, here, here, and here]. Contributions can include (but are not limited to):

- Helping to guide discussion
- Expertise on a particular topic
- Design or production of figures
- Taking notes of discussion points
- Actively participating in discussion
- Providing key literature

Each group will submit one Contribution Statement for the project presentation, and each statement must be agreed on by all group members prior to submission.

Skills – This component of the course should be very little work, and is primarily meant to keep everyone mindful of engaging in effective collaboration and being a productive group member. Effective collaboration requires articulating ideas to collaborators, listening to alternative perspectives, reaching consensus, delegating responsibility, coordinating effort, and resolving conflicts. Collaborative work is also far more productive and satisfying when all participants feel tangible ownership over some aspect of the work, and that their collaborators are accountable for their engagement with group tasks.

Support and Resources @ Georgia Tech:
If you are a student with needs, whether apparent or non-apparent, learning, emotional, physical, or cognitive that require special attention, or if you find yourself in need of support for any reason, we maintain a Support and Resources @ Georgia Tech page with a number of avenues for support. Please do not hesitate to approach me with any questions, concerns, or issues you may have. I am committed to creating a learning environment in which all students feel valued, respected, safe, and included.

Serve-Learn-Sustain [SLS]
Georgia Tech's Serve-Learn-Sustain (SLS) initiative provides students with opportunities to combine their academic and career interests with their desire to make worthwhile contributions to the world and build sustainable communities where people and nature thrive, in Georgia, the United States, and around the globe. More information about SLS can be found at https://serve-learn-sustain.gatech.edu/.

Topic List:

Week	Topic	Resources
W1	Intro	–
W2	Carbon cycle fundamentals	IPCC AR5 WG1 Ch6 [465-475]
W3	What is CDR and why is it needed?	SoCDR [17-23 | 162-180]
W4	Taxonomy of CDR pathways	IPCC AR6 WG1 Ch5 [755-766]
W5	Guided Discussion	–
W6	Measurement, reporting, and verification [MRV]	WRI MRV Report
W7	Life cycles and technoeconomics	Chiquier et al. [2022]
W8	Ethics and social justice	IRCR Report 2024
W9	Fall Break | Open discussion	–
W10	Project Work Week 1	–
W11	Project Work Week 2	–
W12	Project Work Week 3	–
W13	Project Presentations	Assigned by Groups
W14	Project Presentations	Assigned by Groups
W15	No class – Thanksgiving Break	–
W16	House cleaning / open discussion	–